Air Compressors – DOE's Current Regulations

U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

EERE Building Technologies and the Office of Enforcement
U.S. Department of Energy
May 24, 2022

PURPOSE OF THE WEBINAR

- Walk through the current compressors regulations before compliance is required with energy conservation standards
- Review testing, rating, certification, and compliance responsibilities
- Not a forum to seek changes to regulations or seek opinions of the existing regulations.

AGENDA

1. **INTRODUCTION; AUTHORITY; BACKGROUND; CFR**
2. TEST PROCEDURE [SCOPE, REP. REQUIREMENTS, OUTPUT]
3. BASIC MODEL
4. DETERMINATING REPRESENTED VALUES (TESTING)
5. DETERMINATING REPRESENTED VALUES (AEDM)
6. ENERGY CONSERVATION STANDARDS
7. CERTIFICATION
8. ENFORCEMENT

INTRODUCTION

This presentation summarizes information and requirements related to DOE's various energy conservation regulations of certain compressors.

- This presentation is a summary of certain compressors regulations, but not a regulation, itself. In the event of any apparent disagreement between this presentation and the language of the regulations contained in Code of Federal Regulations ("CFR"), the CFR prevails.

- More information may be found on the compressors rulemaking webpage: https://www1.eere.energy.gov/buildings/appliance_standards/standards.aspx?productid=63

REGULATIONS; CFR

Regulations for air compressors reside in the Code of Federal Regulations ("CFR").

- Most applicable applications reside in either:
  - Part 429 of Title 10 (Compliance, Certification, and Enforcement)
    - https://www.ecfr.gov/current/title-10/chapter-II/subchapter-D/part-429?toc=1
  - Subpart T of Part 431 of Title 10 (Scope, Definitions, Test Procedure, Energy Conservation Standards)
    - https://www.ecfr.gov/current/title-10/chapter-II/subchapter-D/part-431/subpart-T

RULEMAKING BACKGROUND

DATE	ACTION	REFERENCE
Nov. 15, 2016	DOE publishes a notice of final determination, which determined that coverage for compressors is necessary to carry out the purposes of Part A–1 of Title III of EPCA.	81 FR 79991
Jan. 4, 2017	DOE publishes a final rule to establish new test procedures pertaining to certain compressors.	82 FR 1052
Feb. 2 & Mar 21, 2017	DOE publishes a notice of delay of effective date of final rule establishing test procedures for compressors.	82 FR 8985; 82 FR 14426
July 11, 2017	DOE publishes a request for information regarding costs of implementing test procedure.	82 FR 31890
May 17, 2019	DOE publishes notice of petition for rulemaking pertaining to test procedures for compressors.	84 FR 22395
Jan. 10, 2020	DOE publishes a final rule establishing energy conservation standards for certain compressors.	84 FR 22395
May 6, 2022	DOE issues RFI to consider whether to amend DOE test procedure for compressors, announces this “compressors 101” webinar, and pulls down enforcement policy regarding compressors test procedure as of May 2.	87 FR 27025

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AIR COMPRESSOR DEFINITIONS

- Compressor
  - means a machine or apparatus that converts different types of energy into the potential energy of gas pressure for displacement and compression of gaseous media to any higher pressure values above atmospheric pressure and has a pressure ratio at full-load operating pressure greater than 1.3 (10 CFR 431.342).
- Air Compressor
  - means a compressor designed to compress air that has an inlet open to the atmosphere or other source of air, and is made up of a compression element (bare compressor), driver(s), mechanical equipment to drive the compressor element, and any ancillary equipment (10 CFR 431.342).

SCOPE OF TEST PROCEDURE

TP applies to compressors meeting following criteria (10 CFR 431.344(a)):

1. Is an air compressor;
2. Is a rotary compressor;
3. Is not a liquid ring compressor;
4. Is driven by a brushless electric motor;
5. Is a lubricated compressor;
6. Has a full-load operating pressure greater than or equal to 75 pounds per square inch gauge (psig) and less than or equal to 200 psig.
7. Has full-load actual volume flow rate greater than or equal to 35 cubic feet per minute (cfm), or is distributed in commerce with a compressor motor nominal horsepower greater than or equal to 10 horsepower (hp);
8. Has a full-load actual volume flow rate less than or equal to 1,250 cfm or is distributed in commerce with a compressor motor nominal horsepower less than or equal to 200 hp.
9. Is not designed and tested to the requirements of the American Petroleum Institute Standard 619, "Rotary-Type Positive-Displacement Compressors for Petroleum, Petrochemical, and Natural Gas Industries;"

TEST PROCEDURE OUTPUTS

The following quantities are determined by using test procedure for compressors (Appendix A to Subpart T of 10 CFR 431):

- Package isentropic efficiency (ηisen,FL)
  - *"The ratio of power required for an ideal isentropic compression process to the actual packaged compressor power input used at a given load point, as determined in accordance with the test procedures prescribed in 10 CFR 431.344."* 10 CFR 431.342.
  - Two distinct varieties of this quantity ("full-load" and "part-load") have separate testing instructions respectively provided in sections II.C and II.D of Appendix A to Subpart T
- Package specific power
  - *"The compressor power input at a given load point, divided by the actual volume flow rate at the same load point, as determined in accordance with the test procedures prescribed in 10 CFR 431.344."* 10 CFR 431.342.
- Maximum full-flow operating pressure
  - *"The maximum discharge pressure at which the compressor is capable of operating, as determined in accordance with the test procedure prescribed in 10 CFR 431.344."* 10 CFR 431.342.

TEST PROCEDURE OUTPUTS

The following quantities are determined by using test procedure for compressors (Appendix A to Subpart T of 10 CFR 431):

- Full-load operating pressure
  - A self-declared value greater than or equal to the lesser of (A) 90 percent of the maximum full-flow operating pressure, or (B) 10 psig less than the maximum full-flow operating pressure.
  - ("Full-load operating pressure" has no formal definition but is specified by section III.C.4. of Appendix A to Subpart T of Part 431)
- Full-load actual volume flow rate
  - *"The actual volume flow rate of the compressor at the full-load operating pressure."* 10 CFR 431.342.
- Pressure ratio at full-load operating pressure
  - *"The ratio of discharge pressure to inlet pressure, determined at full-load operating pressure in accordance with the test procedures prescribed in 10 CFR 431.344."* 10 CFR 431.342.

ENERGY EFFICIENCY METRIC

The energy metric for compressors is **Full-Load Package Isentropic Efficiency** or **Part-Load Package Isentropic Efficiency**, which is:

- The ratio of power required for an ideal isentropic compression process to the actual packaged compressor power input used at a given load point, as determined in accordance with the test procedures prescribed in 10 CFR 431.344.
- Package Isentropic Efficiency will be measured for either fixed-speed or variable-speed compressors.
  - Fixed-Speed: Compressor cannot adjust speed of the driver, uses full-load package isentropic efficiency.
  - Variable-Speed: Compressor can adjust the speed of the driver in response to changes in compressor actual volume flow rate, uses part-load package isentropic efficiency.

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BASIC MODEL & INDIVIDUAL MODEL

- A basic model is a DOE regulatory concept. Each basic model of compressor is subject to DOE energy conservation standard regulations.

- A Basic Model means all units of a class of compressors manufactured by one manufacturer, having the same primary energy source, the same compressor motor nominal horsepower, and essentially identical electrical, physical, and functional (or pneumatic) characteristics that affect energy consumption and energy efficiency.
  - See 10 CFR 431.342 for full definition

- An individual, or manufacturer's, model number is the identifier a manufacturer uses to identify uniquely the group of identical or essentially identical covered products or covered equipment to which a particular unit belongs. This model number typically appears on the product nameplates, in product catalogs and in other product advertising literature.
  - See 10 CFR 429.2

- A basic model may include more than one manufacturer model number. All the ratings within a basic model of individual models must be the same and representative of the least efficient one in the grouping.

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DETERMINING REP. VALUES - TESTING

Manufacturers must determine the represented value ("RV"), which includes the certified rating, for each basic model of compressor either by testing in conjunction with the applicable sampling provisions or by applying an AEDM.

- If RV is determined through testing, general requirements of 10 CFR 429.11 apply:
  - Units must be production (or representative thereof)
  - Selection of units must be random (not "cherry-picked")
  - Components of similar design may be substituted if it does not affect efficiency.
  - All RVs of energy efficiency or consumption must be the same for all individual models represented within a given basic model.
  - At least two units of each basic model must be tested
    - If only one unit exists, test that one. If more units are built later, test at least one more.

DETERMINING REP. VALUES - TESTING

- Representations of full- or part-load package isentropic efficiency or other measure of efficiency of a basic model must be less than or equal to the lower of:

    1. **The arithmetic mean of the sample:**

    $$\bar{x} = \frac{1}{n}\sum_{i=1}^{n} x_i$$

    Where $\bar{x}$ is the sample mean; n is the number of samples; and xi is the measured value for the i^{th} sample

    2. **The lower 95% confidence limit of arithmetic mean divided by 0.95:**

    $$LCL = (\bar{x} - t_{0.95} * \left(\frac{s}{\sqrt{n}}\right))$$

    And $\bar{x}$ is the sample mean; s is the sample standard deviation; n is the number of samples; and $t_{0.95}$ is the t statistic for a 95 percent one-tailed confidence interval with n−1 degrees of freedom

- Representative value(s) of package specific power of a basic model must be the mean of the package specific power measurement(s) for each tested unit of a basic model.

DETERMINING REP. VALUES - TESTING

- Although the limits on the previous slide enforce a maximum permitted isentropic efficiency rating, they do not enforce a minimum.
- Manufacturers may choose to rate basic models more conservatively than the representation requirements specify.
- *Example:* if a Basic Model X is found through testing to have sample arithmetic mean (full- or part-load package isentropic) efficiency of 50% and LCL divided by 0.95 of 45%, then the efficiency representation must be <= 45%. A manufacturer could choose to certify Basic Model X at 40% efficiency but not 46% or 51%.
- Once compliance with standards is required, the standard level for that compressor would be the minimum permitted rating.

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ALTERNATIVE EFFICIENCY DETERMINATION METHOD (AEDM)

An AEDM is a mathematical model that is an alternative to physical testing that can be used to generate efficiency values for compressors under certain circumstances.

- In lieu of testing, a represented value of efficiency for a basic model of a compressor may be determined through the application of an AEDM, where:
  - Any represented values of package isentropic efficiency or other measure of energy consumption of a basic model for which customers would favor higher values must be less than or equal to the output of the AEDM.
  - Any represented values of package specific power, pressure ratio at full-load operating pressure, full-load actual volume flow rate, or full-load operating pressure must be the output of the AEDM corresponding to the represented value of package isentropic efficiency determined in 10 CFR 429.63.

- See AEDM requirements in 10 CFR 429.70 and 10 CFR 429.63.

AEDM - VALIDATION

Before using AEDM, manufacturer must validate its accuracy and reliability.

- Manufacturer must select at least 2 basic models for each validation class (*i.e.,* fixed- or variable- speed) to which AEDM applies. (429.70(h)(2)(ii))
  - Use AEDM to calculate energy use/efficiency for each selected basic model.
  - Test each basic model; determine rep. values in accordance with 429.63(a)
  - Compare respective results of testing and AEDM output according to 429.70(h)(2)(ii)

AEDM Basic Model Tolerances

- Predicted rep. values for each basic model calculated via AEDM must not be >= (for efficiency values) or <= (for consumption values) 5% of rep. values determined via testing.
- AEDM-predicted package isentropic efficiency for each basic model must meet or exceed applicable energy conservation standard.

AEDM - VALIDATION

Additional Test Unit Requirements – AEDM Validation

- Each AEDM must be supported by test data obtained via physical testing of current models.
- Test results used to validate AEDM must meet or exceed current applicable federal standards.
- Each test must have been performed in accordance with DOE test procedure in effect at time the basic models being used for validation are distributed in commerce.

DETERMINING REP. VALUES - AEDM

The general AEDM requirements of 10 CFR 429.70 apply:

- Manufacturer may not use AEDM to knowingly overrate efficiency.
- Must be derived from mathematical model. 10 CFR 429.70 (h)(1).
- Based on engineering/statistical analysis, simulation, modeling, or other analytical evaluation of performance data. 10 CFR 429.70 (h)(1).
- AEDM has been validated in accordance with 10 CFR 429.70 (h)(2).

DETERMINING REP. VALUES – AEDM

The AEDM requirements specific for compressors of 10 CFR 429.63 apply:

- Any represented values of package isentropic efficiency or other measure of energy consumption of a basic model for which customers would favor higher values must be less than or equal to the output of the AEDM. 10 CFR 429.63(a)(2)(i).

- Any represented values of package specific power, pressure ratio at full-load operating pressure, full-load actual volume flow rate, or full-load operating pressure must be the output of the AEDM corresponding to the represented value of package isentropic efficiency determined in previous paragraph. 10 CFR 429.63(a)(2)(ii).

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ENERGY CONSERVATION STANDARDS

Air compressors must comply with energy conservation standards beginning January 10, 2025. 10 CFR 431.345(a).

- Full-load package isentropic efficiency or part-load package isentropic efficiency must be not less than the appropriate "Minimum Package Isentropic Efficiency" value listed below:

Equipment class	Minimum package isentropic efficiency	η_{Regr} (package isentropic efficiency reference curve)	d (percentage loss reduction)
Rotary, lubricated, air-cooled, fixed-speed compressor	$\eta_{Regr} + (1 - \eta_{Regr}) * (d/100)$	$-0.00928 * \ln^2(.4719 * V_1) + 0.13911 * \ln(.4719 * V_1) + 0.27110$	−15
Rotary, lubricated, air-cooled, variable-speed compressor	$\eta_{Regr} + (1 - \eta_{Regr}) * (d/100)$	$-0.01549 * \ln^2(.4719 * V_1) + 0.21573 * \ln(.4719 * V_1) + 0.00905$	−10
Rotary, lubricated, liquid-cooled, fixed-speed compressor	$.02349 + \eta_{Regr} + (1 - \eta_{Regr}) * (d/100)$	$-0.00928 * \ln^2(.4719 * V_1) + 0.13911 * \ln(.4719 * V_1) + 0.27110$	−15
Rotary, lubricated, liquid-cooled, variable-speed compressor	$.02349 + \eta_{Regr} + (1 - \eta_{Regr}) * (d/100)$	$-0.01549 * \ln^2(.4719 * V_1) + 0.21573 * \ln(.4719 * V_1) + 0.00905$	−15

Note: V^1 represents full-load actual volume flow rate in cubic feet per minute in accordance with 10 CFR 431.344.

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CERTIFICATION: BASICS

- DOE requires certification of each basic model subject to an energy conservation standard beginning once compliance with ECS is required:
  - Submit before distributing any new basic model in commerce.
  - Submit annually.
  - Must update to reflect discontinuance.

- Certification Report:
  - Report states that the basic models reported therein have been tested in accordance with the DOE test procedure and that the basic model complies with the standards.
  - DOE requires both general and equipment-specific information about each basic model, including a certified rating.
  - Ensure that you certify all variations of all individual model numbers.

- Certification responsibility falls on manufacturer if they reside in the U.S., or the importer of the product.

- Certification requirements for compressors are located at 10 CFR Part 429, Subpart B and general certification requirements of 10 CFR 429.12 are applicable.

WHAT DO I SUBMIT?

- Reports are submitted electronically to the Compliance Certification Management System (CCMS). *www.regulations.doe.gov/ccms*

- Download component specific certification templates

- Input component specific information and upload
  - Must report rated values as previously described.
  - Manufacturers are required to certify each individual model with each brand name that it is sold under.
  - Must report component specific characteristics.
  - Must certify in legally binding statement that components have been tested in accordance with DOE requirements and that they meet applicable standards.

- Test reports should not be uploaded

CERTIFICATION (CONT'D)

A certification report must include the following public product-specific information (10 CFR 429.63):

- Full-load package isentropic efficiency (or part-load) (dimensionless)
- Full-load actual volume flow rate (in cubic feet per minute)
- Compressor motor nominal horsepower (in horsepower)
- Full-load operating pressure (in pounds per square inch, gauge)
- Pressure ratio at full-load operating pressure (dimensionless)

CERTIFICATION (CONT'D)

Specific information that needs to be reported about ancillary equipment includes:

- A general description of the ancillary equipment based on the list provided in Table 1 of 10 CFR part 431, subpart T, appendix A, section I(B)(4).
- The manufacturer of the ancillary equipment.
- The brand of the ancillary equipment (if different from manufacturer).
- The model number of the ancillary equipment.
- The serial number of the ancillary equipment (if applicable).

CERTIFICATION (CONT'D)

For ancillary equipment, the following must be reported if applicable.

- The following electrical characteristics:
  - Input Voltage
  - Number of Phases
  - Input Frequency
- The following mechanical characteristics:
  - Size of any connections
  - Type of any connections
- Installation instructions for the ancillary equipment, accompanied by photos that clearly illustrate the ancillary equipment, as installed on compressor package (to be provided in a PDF file).

CCMS - Links

- Getting Started in CCMS and Helpful CCMS Information
  - https://www.regulations.doe.gov/ccms/help
  - https://www.regulations.doe.gov/ccms/help/CCMS_User_Guide

- CCMS Technical Support
  - (505) 663-1302
  - ccms.support@ee.doe.gov or https://www.regulations.doe.gov/ccms/help/contact-us

THIRD-PARTY SUBMITTERS

- A manufacturer may elect to use a third party to submit the certification report to DOE (e.g., an independent test lab, or companies that assemble products abroad but do not import them) (10 CFR 429.12(g)).

- Manufacturer is still responsible for submission of the certification report to DOE:
  - The manufacturer remains responsible for the accuracy of the reports and compliance with the standards.
  - Manufacturers using a third-party submitter must complete an authorization form.

- To complete a third-party certification report properly:
  - A manufacturer must complete a third-party authorization form and provide it to the third-party to submit to DOE.
  - The third-party representative must have a CCMS account.
  - The third-party's certification on behalf of the manufacturer must indicate the third-party is a third-party representative and must identify the party on whose behalf the report is being submitted. It must also indicate whether that party is a domestic manufacturer or importer.

OTHER REPORTS

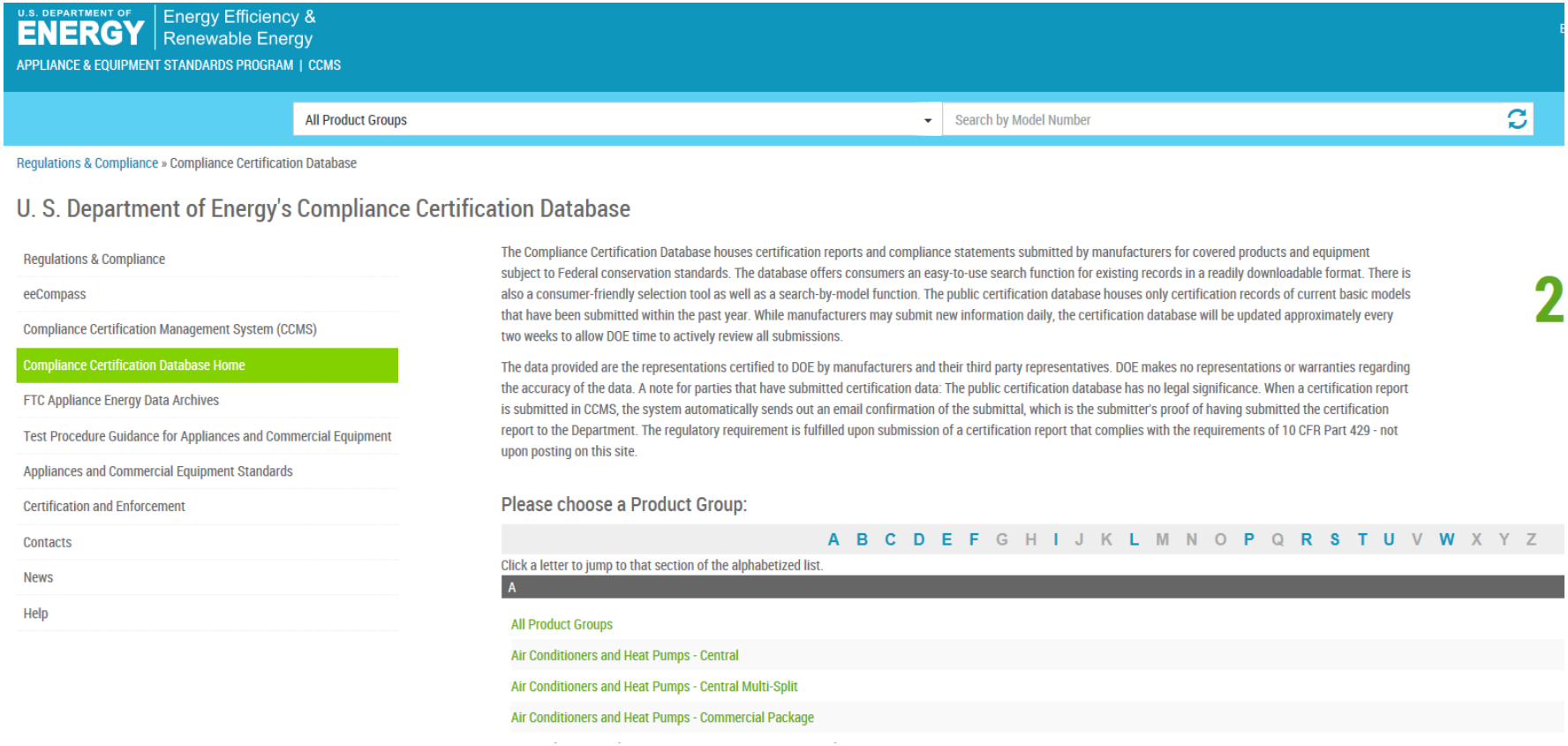
- Reporting to other regulatory or voluntary programs (*e.g.*, CAGI's "Performance Verification" Program) does **NOT** satisfy the DOE certification requirement.

- Even if you have reported models to another program or agency, you still must certify to DOE that the products you distribute in commerce meet the applicable standard.

- Ratings reported to DOE must be the same as those reported to other agencies and placed on product packaging and marketing literature.

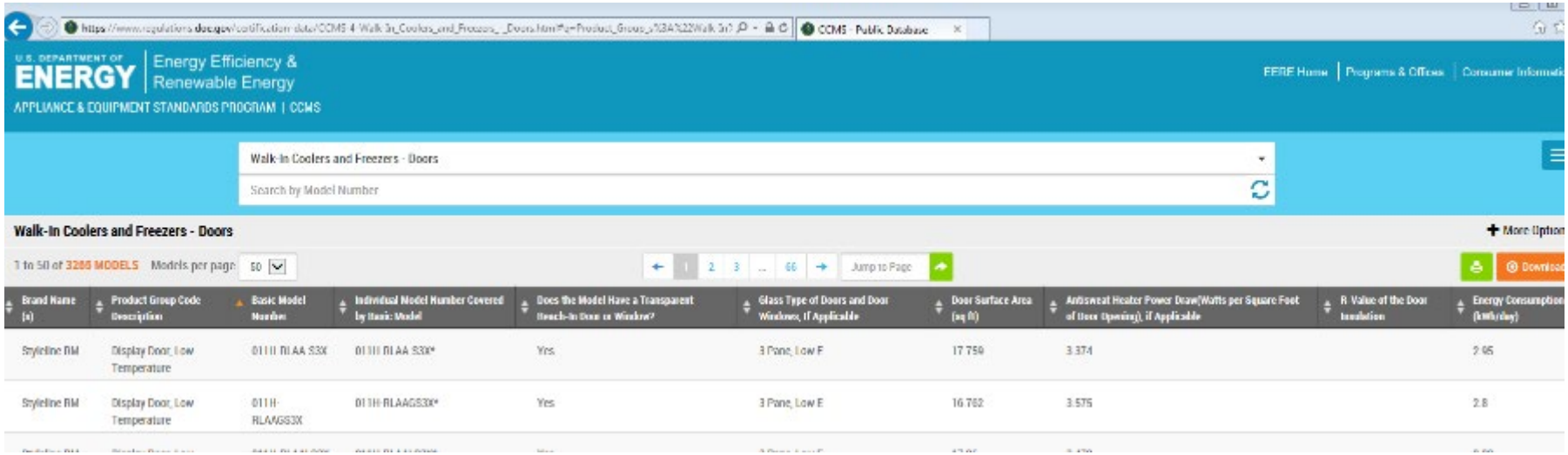
PUBLIC CCMS DATABASE

Models are typically added to DOE public certification database within two weeks: http://www.regulations.doe.gov/certification-data



PUBLIC CCMS DATABASE (CONT'D)

- DOE does not publish manufacturer/brand name relationship.
- Public database lists models by brand name, **not** manufacturer.
- Database houses only certification records of current basic models that have been submitted within the past year.
- The posting of a model on the public certification database has no legal significance.
- DOE may not publish all submissions. Your e-mail confirmation that a certification submission has been received is your "receipt" – not publication in CCMS database.



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ENFORCEMENT

- Any representations made, even prior to the Jan 2025 effective date, must be based on testing in accordance with the DOE TP and applicable sampling provisions.

- DOE enforces energy conservation standards once compliance is required.
  - *DOE can order manufacturers to take corrective action if their products do not meet the standard levels. This can include a warning, request for data, notice of noncompliance determination, additional certification testing requirements, the imposition of civil penalties, and ordering manufacturers to not to sell the products in the United States.*

- DOE conducts enforcement testing in accordance with enforcement testing provisions

- Additional information
  - General Enforcement Provisions: 10 CFR 429 Subpart C
    - https://www.ecfr.gov/current/title-10/chapter-II/subchapter-D/part-429/subpart-C
  - Product-specific enforcement provisions: 10 CFR Part 429.134(p)
    - https://www.ecfr.gov/current/title-10/chapter-II/subchapter-D/part-429/subpart-C/section-429.134

Questions

Jeremy Dommu

appliancestandardsquestions@ee.doe.gov